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DILUTION CENTRIFUGING OF BITUMEN FROTH
FROM THE HOT WATER PROCESS FOR TAR SAND

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Granted to Her Majesty the Queen in right of Canada,
as represented by the Minister of Energy, Mines and
Resources, Canada; Her Majesty the Queen in right of
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ABSTRACT

In the known operation wherein naphtha-diluted bitumen froth is pumped from a scroll-type centrifugal separator to a disc-type centrifugal separator, an improved pumping system is provided. The system comprises at least two centrifugal pumps in series, each operating at less than 65% of design capacity. The invention is based on the discovery that dilution with naphtha greatly increases the emulsification tendency of the froth components; therefore it is necessary to reduce shearing of this stream to keep the solids and water content of the disc product within a desirable limit. This is achieved by using staged pumps and operating the pumps at a relatively low tip speed.

This invention relates to a method for treating bitumen froth produced from tar sand by a hot water extraction process plant. More particularly it relates to a system for pumping froth, diluted with hydrocarbon, from a scroll-type centrifugal separator to a disc-type centrifugal separator within the two-stage centrifuge circuit that is conventionally used to recover the bitumen from the froth.

One of the world's largest reservoirs of hydrocarbons is the Athabasca tar sand deposit in Northern Alberta. The oil or bitumen from this deposit is presently being extracted using the known hot water process.

In general terms, this process involves mixing tar sand with water and steam in a rotating tumbler to initially separate the bitumen from the water and solids of the tar sand and to produce a slurry. The slurry is diluted with additional water as it leaves the tumbler and is introduced into a cylindrical primary settler vessel having a conical bottom. The largest part of the coarse sand particles settles out in this vessel and is removed as an underflow and discarded. Most of the bitumen and minor amounts of solids and water form a froth on the surface of the vessel contents. This froth overflows the vessel wall and is received in a launder extending around its rim. It is referred to as primary froth. A middlings stream, comprising water, fine solids (-325 mesh), and a minor amount of buoyant and non-buoyant bitumen, is withdrawn from the mid-section of the vessel and is pumped to a sub-aeration flotation cell. Here the middlings are agitated and aerated to an extent greater than that within the primary vessel. The middlings bitumen and some water and solids become attached to the air bubbles and rise through the cell contents to form a froth. This froth, referred to as secondary froth, is recovered in a launder and is then settled to reduce its water and solids



content. The primary froth and settled secondary froth are combined and preferably deaerated and heated with steam in a column. Typically the deaerated froth comprises 62% bitumen, 29% water and 9% solids. The temperature of the froth after deaeration is typically 185°F.

Following deaeration, the froth is pumped through a feed conduit to a two-stage dilution centrifuging circuit. In the first step of this circuit, a hydrocarbon diluent is injected into the feed conduit to mix with the froth. The diluent, usually naphtha, is added to reduce the viscosity and specific gravity of the froth bitumen phase and render it amenable to centrifugal separation. The diluted froth is then treated in one of a battery of scroll separators. This separator removes most of the coarse particles from the froth being treated. The scroll product is then pumped through one of a battery of disc separators to remove the remaining fine solids and water and produce a relatively clean, diluted bitumen stream.

It is known that emulsification of the bitumen, solids and water takes place as the froth moves through the process. This emulsification affects the quality of the bitumen product obtained from the disc separators. That is, the water and solids content of the disc product increases due to upstream emulsification.

In order to obtain a disc product which is acceptable for utilization in downstream bitumen upgrading units, it is conventional to add a chemical demulsifier to the feed stream just before it enters the disc separator. When one considers the size and throughput of a commercial hot water extraction plant, it will be appreciated that the cost for such demulsifier addition is substantial.

In accordance with this invention, it has been discovered that the problematic emulsification of the froth

components occurs after the hydrocarbon diluent has been added. More particularly, as a result of work carried out in a test circuit, it has been found that if the deaerated froth is rigorously agitated in a mixing tank prior to the addition of naphtha, and if a low shear progressive cavity pump is used to transfer the product from the scroll separator to the disc separator, then the water and solids content in the disc separator product is relatively low, i.e. in the order of 5% by volume or less. However, when a commercial-type high shear centrifugal pump is substituted for the progressive cavity pump in this circuit, the water and solids content of the disc separator product increases substantially and is higher than the 5 - 7% content deemed to be necessary for the downstream refinery-type upgrading units.

Having discovered that emulsification only becomes a serious problem after the hydrocarbon diluent has been added to the froth, and that a centrifugal pump run at high tip speed is the main component acting to emulsify the diluted bitumen and water, we have determined that low shear pumping can successfully be used between the first and second stages of centrifugal separation to reduce emulsification to an acceptable level.

Broadly stated, the invention is an improvement on the known dilution centrifuging process, wherein deaerated bitumen froth is diluted with hydrocarbon (such as naphtha) and is treated in a scroll-type centrifugal separator, to remove coarse solids, and then in a disc-type centrifugal separator, to separate the bitumen from the water and fine solids. The improvement comprises normally pumping the bitumen-rich product stream obtained from the scroll separator to the disc separator using two or more centrifugal pumps in series, each pump being operated at less than about 4000 feet per minute impellor tip speed and substantially less than its rated pumping capacity measured as impellor tip speed.

By "normally" is meant that the pumping system is operated under these conditions during the largest part of its operating time.

In the drawing:

5 Figure 1 is a schematic showing a test circuit, wherein deaerated froth is mixed, diluted with naphtha, treated in a scroll separator and then treated in a disc separator to produce clean bitumen - it is to be noted that the scroll separator product can be pumped by either a progressive cavity
10 pump, centrifugal pump, or staged centrifugal pumps in series through a pressure let-down valve to the disc separator.

Making reference to Figure 1, the test circuit used to develop this invention involved introducing deaerated froth, from a hot water bitumen extraction plant, into a mixer
15 tank 1. Here the froth was retained for a period of time and agitated with mixers 2. The mixed froth was then pumped through a conduit 3 to a scroll separator 4 by a progressive cavity pump 5. Naphtha was introduced into the conduit 3 at a tank
20 6 between the pump 5 and scroll separator 4. The rate of naphtha addition was selected to dilute the froth to a level at which it was amenable to centrifugal separation. On passing the dilute froth through the scroll separator 4, the bulk of the coarse sand particles was removed and discarded as a tailings
25 stream 7 while the bitumen product stream 8 was collected in a tank 9. From this tank, the scroll bitumen product was pumped by either a progressive cavity pump 10, a centrifugal pump 11, or staged centrifugal pumps 12 through a conduit 13, boot valve 14 and filter 15 into a disc separator 16. On passing the scroll
30 bitumen product through the disc separator 16, the water and solids were largely separated and discarded as a tailings stream while the bitumen was recovered.

It was a requirement, arising from our commercial

design of a dilution centrifuging circuit, that the pump means used to feed the scroll bitumen product stream to the disc separator had to develop a discharge pressure of approximately 40 psig. It was found that when this operating condition was observed, the solids plus water content of the disc bitumen product was acceptably low (i.e. about 3.4% or less) when the progressive cavity pump 10 was used; however when the centrifugal pump 11 was used and run at its design capacity, the disc bitumen product contained an unacceptably high solids plus water content (i.e. about 9% or greater). From this it was concluded:

- 10 (a) that the naphtha-free bitumen froth could be subjected to high shear in the mixer tank 1 without that degree of emulsification taking place which would result in a disc bitumen product having an unacceptably high solids plus water content; and
- 15 (b) that subjecting the diluted bitumen scroll product to high shear with the centrifugal pump 11 caused problematic emulsification to occur, with the result that the solids plus water content of the disc product was unacceptably high.

20 With this information in hand, staged pumping using two centrifugal pumps 12, 12 in series was tried. The speed of the pumps was kept low, i.e. the impellor tip speed was kept below 4000 fpm which was substantially less than the rated pumping capacity as measured by impellor tip speed, to reduce the rate at which energy was added to the scroll
25 product being pumped. It was found that, in this manner, a pump system discharge pressure of 40 psig could be obtained in conjunction with a satisfactory solids plus water content in the disc separator product. It now appears that the use of demulsifiers in the process may be

dispensed with.

The invention is exemplified by the following example:

Example 1

5 Deaerated bitumen froth, comprising 62%
bitumen, 29% water and 9% solids and having a temperature of
190°F, was supplied at a rate of 9 IGPM to an 8 foot diameter
by 15 foot long mixer tank 1. The froth was stirred in the
tank 1 for a period of 11 hours by Prochem* 22 inch diameter
10 mixers operating at 420 rpm. Froth was withdrawn from the tank
1 by a 1 L10 Moyno* progressive cavity pump 5 at a rate of
14.7 IGPM and pumped with a discharge pressure of 6 psig
through a conduit 3 to a mixer tank 6. 5.3 IGPM of naphtha,
preheated to 120°F, were injected into the mixer tank 6 to mix
15 with and dilute the bitumen. A 3L6 Moyno pump 7 was used to
pump the diluted froth mixture from the mixer tank 6 to the
scroll separator 4. The delivery pressure at the separator
4 was 2 psig. The scroll separator, a 12 inch x 30 inch Bird*
unit, processed the 170°F stream of dilute deaerated froth
20 at 1350 rpm and produced a bitumen-rich product comprising
72% hydrocarbon, 4% fine solids and 24% water. This product
was received and stored in a tank 8. Feed stock was with-
drawn from the tank 8 and fed to disc separator 16 by either:
(a) a Moyno* 2L6 progressive cavity pump 10; (b) a Crane Deming*
25 1 1/2 inch x 1 inch centrifugal pump 11; or (c) a pair of Crane
Deming* 1 1/2 inch x 1 inch and A.C. 1 1/2 inch x 1 inch
centrifugal pumps 12 in series.

More particularly, froth was withdrawn from
the tank 8 and pumped through a conduit 13, Brown* fintube heater
30 17, Fisher* 1 inch boot valve 18, and basket strainer filter 19
into a De Laval* SX 204T disc separator 16. Results of the
comparative runs through the three pump systems are given in
Table I:

*trade mark

Table I

	<u>Pump</u>	<u>Feedrate (IGPM)</u>	<u>Pump discharge pressure (psig)</u>	<u>% H₂O + solids in product</u>
5	Progressive cavity	5.6	40	3.4
	Single centrifugal	5.6	41	8.9
	Two centrifugal in series	5.6	39	6.1

10 SUPPLEMENTARY DISCLOSURE

This supplementary disclosure presents an additional example to illustrate the staged pumping system of the principal disclosure.

In the drawings:

15 Figure 2 is a plot of the contamination of the diluted bitumen product of the disc separator as a function of the impellor tip speed for both one and two-stage centrifugal pumps; and

20 Figure 3 is a plot of the contamination of the diluted bitumen product of the disc separator as a function of the pump discharge pressure for both one and two-stage centrifugal pumps.

25 It was discovered that the dilution of bitumen froth with naphtha greatly increased the emulsification tendency of froth components in a dilution centrifugation circuit which follows the hot water extraction process. To prevent emulsification and thereby keep the solids and water content of the product of the disc centrifuge within a desirable limit, it became necessary to reduce the shearing of the diluted bitumen stream.

30 It was hypothesized that, if the flowrate to the disc separator is kept constant, the amount of energy imparted to the diluted bitumen stream is directly proportional

to the discharge pressure of the pumping unit while the rate at which this energy is imparted is directly proportional to the shear rate, or alternatively, to the impellor tip speed. Therefore, staged pumping using two centrifugal pumps 12, 12 in series was tried.

The invention is exemplified by the following example:

Example 2

Table 2 presents grouped and averaged data of centrifugal pump tests. Although many experiments were conducted the data contained a large amount of scatter, probably due to the significant changes in the froth character which were encountered during the experiments. To average out the scatter, the data for each of the one and two-stage pump tests was divided into three groups and averaged within the group. The average feedrate to the DeLaval* disc separator was approximately the same for all of the tabulated tests, and the capacitance tank pressure was maintained at 10 psig throughout.

Table 2

<u>No. of stages</u>	<u>Tip Speed (fpm)</u>	<u>Pump Discharge Press (psig)</u>	<u>Vol. % Water & Solids in Product</u>
1	2460	12	8.3
1	3810	28	8.4
1	5010	49	12.4
2	2640	27	8.9
2	3560	50	8.6
2	4470	78	14.7

The above averaged data is graphically shown in Figures 2 and 3.

As the degree of emulsification of the diluted bitumen stream increases the separation of the bitumen from

the water and solids is poorer. Therefore, Figure 2 can be viewed as a plot of the degree of emulsification as a function of the rate of imparting energy to the diluted bitumen stream. Data for both the one and two-stage pumps show that the degree of emulsification, or the volume percentage of water and solids in the diluted bitumen product of the disc separator, is worse at impellor tip speeds of 4000 - 5000 fpm than at tip speeds of 2500 - 3500 fpm. Figure 2 also shows that the two-stage pump causes a higher degree of emulsification than a one-stage pump at tip speeds in the range of 4000 - 5000 fpm. However, for a given impellor tip speed, the amount of energy imparted by the two-stage pump is twice the amount imparted by the one-stage pump.

Figure 3 is a plot of the volume percentage of water and solids in the diluted bitumen product of the disc separator as a function of the pump discharge pressure for both the one and two-stage pumps. As stated earlier, the pump discharge pressure is a measure of the amount of energy imparted to the diluted bitumen stream by the pump. At a fixed discharge pressure, for example of 50 psig, the amount of energy absorbed by the diluted bitumen stream from the one-stage pump is exactly the same as from the two-stage pump. However, the one-stage pump would have to run at a higher impellor tip speed than the two-stage pump in order to supply the same amount of energy. Figure 3 shows that for a required pump discharge pressure of 50 psig, the one-stage pump with a relatively high tip speed has increased the degree of emulsification while the two-stage pump with a relatively low tip speed has not.

By keeping the impellor tip speed of two centrifugal pumps in series low, a pump system discharge pressure of 40 psig could be obtained in conjunction with a satisfactory

solids plus water content in the diluted bitumen product of the disc separator. It now appears that the use of demulsifiers in the process may be dispensed with.

5 In summary, it is proposed to use multiple pumps operated at an impellor tip speed substantially less than the rated pumping capacity to introduce the energy into the diluted bitumen stream needed to feed the stream to the second stage separators at the required feed pressure.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE
PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. In a dilution centrifuging process wherein deaerated
bitumen froth, comprising bitumen, water and coarse and fine solids, is
5 diluted with hydrocarbon and is treated in a scroll-type centrifugal
separator, to remove coarse solids, and then in a disc-type centrifugal
separator, to separate the bitumen from the water and fine solids,

the improvement which comprises:

10 normally pumping the bitumen-rich product stream obtained from
the scroll separator to the disc separator using two or more centrifugal
pumps in series, each pump being operated at less than about 4000 feet per
minute impellor tip speed and substantially less than its rated pumping
capacity measured as impellor tip speed.



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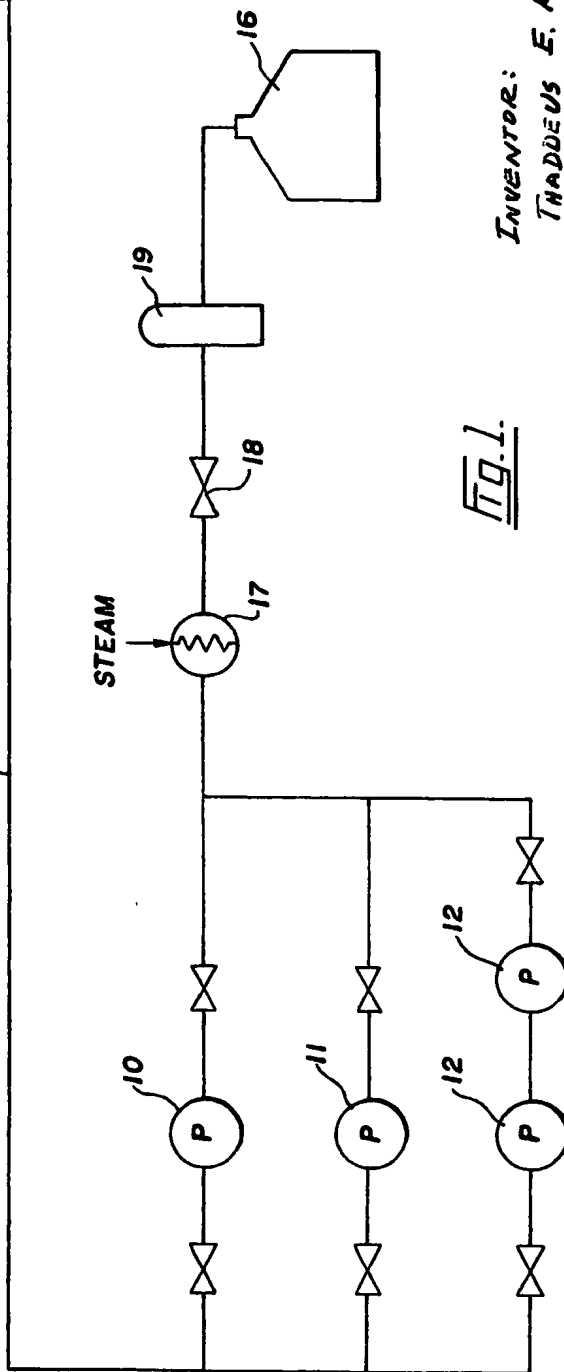
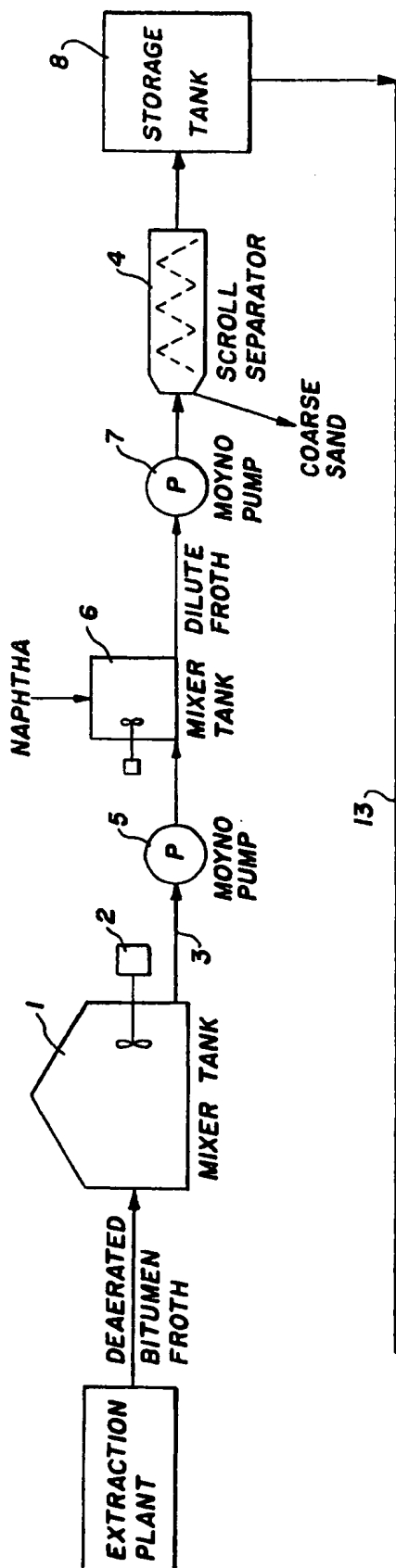


FIG. 1.

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Fig. 2.

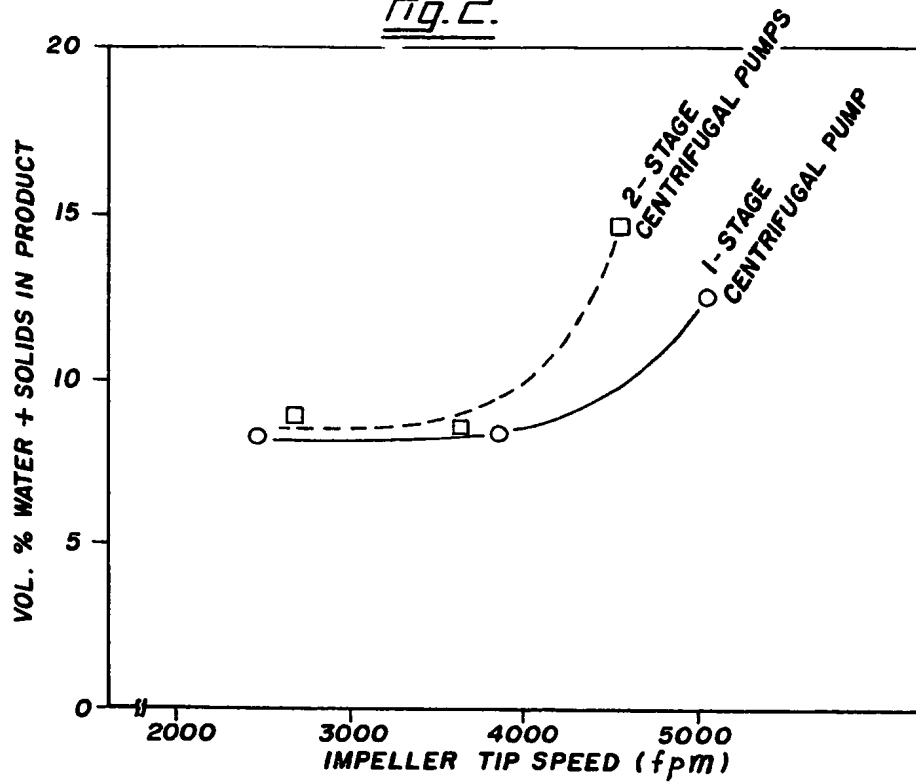
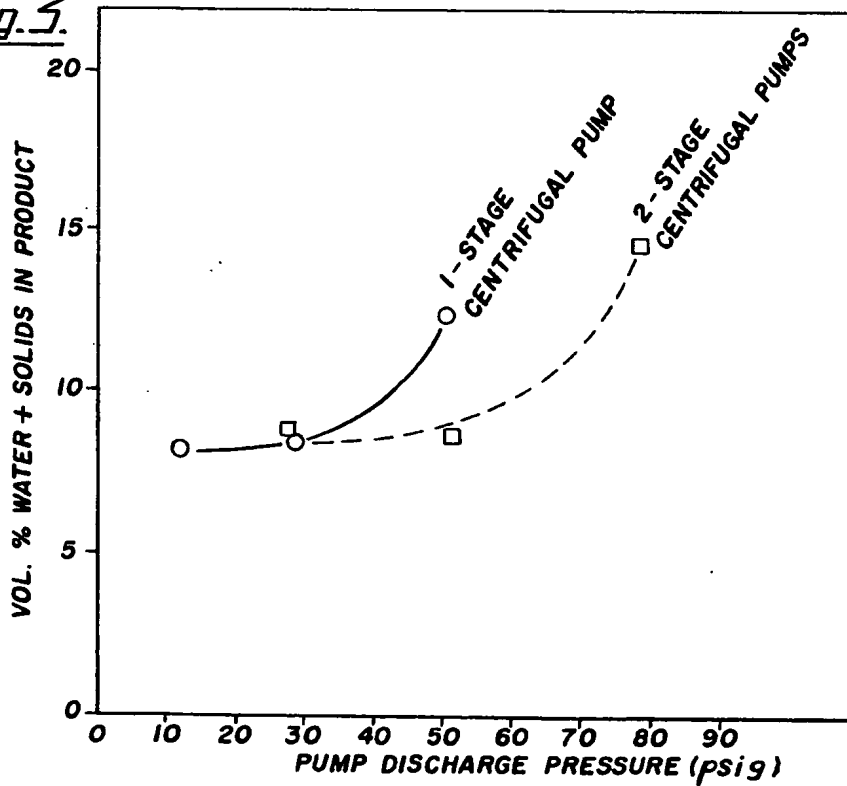


Fig. 3.



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